1-1-2012

Necessary competencies for computer-based construction estimating curriculum: Delphi study of an expert panel

Ryan Schulz
Eastern Illinois University

THESIS MAINTENANCE AND REPRODUCTION CERTIFICATE

TO: Graduate Degree Candidates (who have written formal theses)

SUBJECT: Permission to Reproduce Theses

An important part of Booth Library at Eastern Illinois University's ongoing mission is to preserve and provide access to works of scholarship. In order to further this goal, Booth Library makes all theses produced at Eastern Illinois University available for personal study, research, and other not-for-profit educational purposes. Under 17 U.S.C. § 108, the library may reproduce and distribute a copy without infringing on copyright; however, professional courtesy dictates that permission be requested from the author before doing so.

By signing this form:

- You confirm your authorship of the thesis.
- You retain the copyright and intellectual property rights associated with the original research, creative activity, and intellectual or artistic content of the thesis.
- You certify your compliance with federal copyright law (Title 17 of the U.S. Code) and your right to authorize reproduction and distribution of all copyrighted material included in your thesis.
- You grant Booth Library the non-exclusive, perpetual right to make copies of your thesis, freely and publicly available without restriction, by means of any current or successive technology, including but not limited to photocopying, microfilm, digitization, or Internet.
- You acknowledge that by depositing your thesis with Booth Library, your work is available for viewing by the public and may be borrowed through the library's circulation and interlibrary departmenst or accessed electronically.
- You waive the confidentiality provisions of the Family Educational Rights and Privacy Act (FERPA) (20 U.S.C. § 1232g; 34 CFR Part 99) with respect to the contents of the thesis, including your name and status as a student at Eastern Illinois Univerity.

Petition to Delay:

I respectfully petition that Booth Library delay maintenance and reproduction of my thesis until the date specified and for the reasons below. I understand that my degree will not be conferred until the thesis is available for maintenance and reproduction.

Date:

Reasons:

Author's Signature

4/23/12 E#: 12050428

Date

This form must be submitted in duplicate.

NECESSARY COMPETENCIES FOR COMPUTER-BASED
CONSTRUCTION ESTIMATING CURRICULUM:
DELPHI STUDY OF AN EXPERT PANEL

BY

Ryan Schulz

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Master of Science in Technology

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

2012
YEAR

I HEREBY RECOMMEND THAT THIS THESIS BE ACCEPTED AS FULFILLING
THIS PART OF THE GRADUATE DEGREE CITED ABOVE

4/23/12		4/23/12	
THESIS COMMITTEE CHAIR OR CHAIR'S DESIGNEE	DATE	DEPARTMENT/SCHOOL CHAIR	DATE
4-23-12			
THESIS COMMITTEE MEMBER	DATE	THESIS COMMITTEE MEMBER	DATE
4-23-12			
THESIS COMMITTEE MEMBER	DATE	THESIS COMMITTEE MEMBER	DATE

ABSTRACT

Universities are continuously updating curriculum to meet the needs of students entering the work force in an ever competitive environment. The construction industry is not immune to this competition and in need of competent estimators proficient in producing highly detailed estimates with the aid of computer based estimating programs.

This study set out to find necessary competencies for college students learning how to use computer based estimating programs that can be transferred to real world situations upon graduation. Using a modified Delphi technique, a panel of experts was established from the construction industry and academia too accurately obtain a set of learning objectives most needed for learners engaged in computer based estimating courses. Through several rounds of questionnaires, expert respondents established twenty four learning objectives of particular importance for incorporation into construction estimating curriculum.

Establishment of these learning objectives suggests further research in creating appropriate learning modules for the findings as well as investigating additional technologies that will further enhance the effectiveness of computer based estimates.

ACKNOWLEDGMENT

I would first like to thank Dr. David Melton for making my graduate education a truly enjoyable experience through his never ending humor, support, and persistence to make this research a reality. His willingness to help individuals succeed in the classroom as well as the workplace is second to none. For his guidance I am forever thankful.

To my entire family, and particularly my parents Jeff and Barb Schulz, who steered me through adolescence and into adulthood, with love and support that never faltered, I am truly blessed. Their sustained guidance allowed me to explore my passion while pushing me not to accept the status quo.

And last but not least, my loving wife Megan, who I met and married after I started researching this topic, I am appreciative of her support and wit through the entire process. In asking if I ever thought I would be married before I completed this research, she was a persistent reminder of my goals and a strong proponent of me reaching them.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

As construction professionals leave college they enter a workforce which requires them to use a variety of tools to be successful construction estimators (Pratt, 2004). Estimates serve as the basis for all construction projects and require various forms of accuracy and detail in different stages of a project (Pratt, 2004). According to Holm (2005), "(Construction) cost estimating involves collecting, analyzing, and summarizing all available data pertaining to a project" (p.28).

Due to the importance of construction estimates, there is a need to update Eastern Illinois University's construction estimating curriculum to meet the need of today's construction environment. This study used an expert panel to determine which essentials of estimating are required to be successful estimators for construction projects. A national Delphi study was used to survey experts in the field of construction estimating, asking them to identify which proficiencies they feel are most important for practicing computer-based construction estimating. From these competencies, universities will be able to develop appropriate curriculum to support their computer-based construction estimating courses.

Purpose and Objectives

The primary purpose of this Delphi study was to (a) acquire a list of skills, through inquire of an expert panel, that are needed to successfully complete a construction estimating course while utilizing computer based estimating programs; and (b) analyze responses of the expert panel to create a set of essential skills for construction estimating professionals. Learning objectives were based around a set of categories in the fields of history and evolution of computer estimates, database creation, takeoffs, use of assemblies, report creation, and miscellaneous items.

Procedures

The main focus of this study was to determine the best learning objectives for students undertaking coursework in the field of construction estimating. Through a national survey, learning objectives were acquired in order to assist universities in establishing proper learning objectives for undergraduate level computer-based construction estimating. Use of a multi round Delphi survey enabled the compilation of a variety of learning objectives geared towards creating a learning module for computer-based construction estimating.

Principle Research Question

A basic research question was analyzed to determine reasonable implications of developing learning objectives in regards to computer-based construction estimating. What computer-based estimating learning objectives are of most significance for college graduates entering the construction industry?

Justification

This study gathered information and opinions of various experts for determining a set of necessary learning objectives for instruction of undergraduates in the construction field. Due to software costs and depth of information needed to teach computer-based construction estimating, many undergraduates do not obtain relevant curriculum with appropriate learning objectives.

Results of this study allow other universities and institutions access to learning objectives for creation of an instructional module to supplement and enhance their computer-based construction estimating courses. The competitive environment in the construction industry has required construction personnel to be increasingly competent in the development and execution of computer-based estimating principles (Fatzinger, 2004).

Definition of Terms

For the purpose of this study, the following words or phrases are defined to clarify the meaning as intended by the author.

Add-ons: The additional costs (also called markups) that contractors add to their estimates. It is cost over and above the actual cost to contractors and represents their indirect costs and budgeted profit. It includes overhead, taxes, profit, and other costs (Sage Software, 2007).

Assembly: An assembly is a collection of items needed to complete a particular unit of work; for example, a wall, a slab, or a door. Assemblies enable you to take off multiple items with a single operation (Sage Software, 2007).

Conceptual Estimate: Uses historical and current data to establish a baseline cost estimate for a project. These numbers are used to show an owner broad anticipated costs of a project (Sage Software, 2007).

Formulas: Formulas are the equations that are used to convert variables into to takeoff quantities (Sage Software, 2007).

Items: Items are the individual building blocks for estimates. They are used to track labor, material, subcontractor, equipment, and other costs (Sage Software, 2007).

Material classes: A material class is a set of material items that share a common characteristic. Grouping similar materials together using material classes makes material acquisition and purchasing more efficient (Sage Software, 2007).

Phases: Phases are organizational units that allow you to group similar types of work or tasks within a database. Estimating uses a numbering system to categorize a database into groups of items with similar characteristics. Phases are sometimes referred to as divisions (Sage Software, 2007).

Subcontractors: Subcontractors are secondary contractors who perform some part of the primary contractor's obligation under the contract (Sage Software, 2007).

Takeoff: Takeoff is the process of selecting and quantifying items for use on the estimate. Takeoff is performed when you select the items required for a job from the database and calculate the quantity of that item needed for the project (Sage Software, 2007).

Work Breakdown Structures (WBS): Work breakdown structures are special codes that enable users to attach user defined information to items in the estimate. If the spreadsheet does not include a column to record the information you need, you can create a WBS code to fulfill this need. You can use WBS codes to create custom spreadsheet sequences and reports (Sage Software, 2007).

Delimitations

Only experts nominated from academia and industry were utilized in the creation of construction cost estimating learning objectives for this study.

Limitations

This study was limited to members of an educational email list-serve along with individuals practicing in the construction industry with relevant experience. An additional limitation was the number of individuals who responded to the initial request for participation in this study. The final limitation is a lack of member response in successive rounds of the study.

Assumptions

The following assumptions are made regarding the research and sample of this study:

1.) Experts practicing estimating in industry

   a.) Have 3 or more years of experience closely working with Sage Timberline Office Estimating or any other computer-based estimating programs.

   b.) Has relevant experience in construction estimating and construction management processes.

   c.) Resides within the United States of America

2.) Academia

   a.) Graduate degree in a technology related field (i.e. Technology, Engineering, etc.)

   b.) Five or more years working in an academic environment with a technology emphasis.

   c.) Resides within the United States of America

Respondents to this survey were required to be from the United States in order to best inform colleges as to the academic and market factors that make computer-based estimating important. A final assumption was made that individuals on the expert panel have no knowledge or contact with other individuals involved in this study.

Summary

Cost estimating is an essential set of skills that allow contractors to put a value on the materials and services they intend to offer. In order to accurately put a value on work being performed, companies must accurately tabulate the quantities and cost of materials and services they intend to provide. Once students graduate and enter a construction management position, estimating allows new hires to thoroughly understand the entire construction progression. Using a computer to calculate, organize and store information involved in construction estimates has drastically increased a contractor's ability to be competitive in today's construction industry. By developing a set of learning objectives, individuals' pursuing a career in construction management will have a competitive advantage over individuals that have little or no knowledge of computer-based construction estimating.

CHAPTER II

REVIEW OF LITERATURE

In preparing for this study, a review of literature was completed to better understand information that is available in the current academic and industrial environment. Despite the fact a variety of resources were found in the area of construction estimating, little information was available on curriculum development for computer-based estimating. Due to a lack of information in construction estimating curriculum development, a review of literature was also completed in the field of curriculum development in the field of technology. Valuable information was found through Eastern Illinois University's Booth Library as well as online academic article database EBSCOhost. Several articles were obtained via inter-library loan available at Eastern Illinois University's Booth Library.

Introduction

Various forms of estimates are used throughout a project to ensure effective use of finances and resources. Estimates are used throughout design, contract negotiations, procurement, and construction process in order to estimate, track, and coordinate the entire project cycle. Accuracy of estimates will vary greatly depending on the meticulous detail an owner, architect, engineer, and contractor delineate in project documents. Project participants require updated estimates throughout the design process to ensure they will produce an accurate representation of the owner's budget constraints. In order to forecast construction cost versus an owner's budget, a feasibility estimate may be performed to determine the viability of a proposed development. Having a feasibility estimate also allows a project to be designed to fit within a specified budget (Holm, Schaufelberger, Griffin, & Cole, 2005).

Another reason for construction estimates is to determine if another alternative may be more practical than a current design. Designers may look at different building techniques and materials to determine if a certain style may better fit into an owner's budget limitations. Cost benefit calculations can easily be analyzed with different estimates in order to determine which component or components will economically reach the owner's requirements (Holm, Schaufelberger, Griffin, & Cole, 2005).

Estimates are used in the bidding process and are essential to companies eager to acquire a particular project. These estimates are prepared by construction contractors to determine their bid amounts for the contract procurement process. Estimates are the driving force behind constructing a project within the parameters set forth by an owner and architect. Often changes occur during construction that was not visible to an owner, architect, engineer or contractor prior to work beginning in the field. In order to be properly compensated for changes above and beyond the supplied construction documents, contractors will often use change orders to show what work was not included in their original estimate. Furthermore, estimates can be used when claims or disputes arise to show the credibility of particular costs. Proper documentation of estimates can help a contractor prove that information being brought forward during a claim has not been falsified (Holm, Schaufelberger, Griffin, & Cole, 2005).

Estimates can further be used during the construction process, to justify which work has been completed in order to recoup payment from a client. A schedule of values is often presented to an owner showing what work has been completed in comparison to an estimate. Once contractors can prove work has been fulfilled, they are able to request payment from a client for that portion of work in place (Holm, Schaufelberger, Griffin, & Cole, 2005).

While all prior estimating principals are used during the construction process, data obtained forming these estimates can be stored in a database to determine current cost trends associated with particular projects. Often a contractor can use prior data to determine how they successfully acquired a particular project, or to determine why they were not awarded a particular project (Holm, Schaufelberger, Griffin, & Cole, 2005).

Types of Construction Estimates

Once requests to determine costs associated with a construction project are made, the estimating process essentially begins to determine project costs and budgets. According to Fatzinger (2004), "estimators may be asked to produce a feasibility (conceptual study), preliminary proposal, or construction proposal. In all cases, the estimator is responsible for an accurate, competitive assessment of the project" (p.5).

Conceptual estimates determine whether or not a project is actually capable of being constructed. Minimal project information is known at this stage of estimating such as a rough sketch, floor plan, site plan, or structural section with very few dimensions or details. Therefore estimates are typically based on project square footage or volume and not detailed information. These estimates are often prepared by architects or engineers to give an owner a broad idea of how much a project will cost (Hendrickson, 2003).

Often conceptual estimates are based on a cost per square foot calculation and lack the essential details needed to proceed with a project. Conceptual estimates are formed with historical data from projects of similar scale and materials in order to give the owner an accurate representation of how much a project will likely cost. The basis of all proceeding estimates are formed off the conceptual estimate and are continuously compared to ensure costs remain as close to an owner's budget as possible (Fatzinger, 2004). The United States

Department of Energy (1997) stated "(Conceptual estimates are) to ensure project feasibility and attainable performance levels; to develop a reliable project cost estimate consistent with realistic schedules; to use it to establish baseline project definitions, schedules, and costs" (p. 4-3).

If a conceptual estimate is within the owner's budget limitations, a preliminary proposal is often produced using more detailed architectural and structural drawings. These 'preliminary plans' are not complete and often lack great details, but often provide items to scale with accurate dimensions. Selected contractors in the field of excavating, concrete, mechanical, electrical, plumbing, etcetera can obtain these preliminary plans to produce accurate estimates of how much their respective area of expertise will cost an owner. Preliminary plans purposely lack complete detail in order for architects to gain information from contractors to determine the best way to construct portions of a project. Fatzinger (2004) states, "Feedback from these contractors assists the architect / engineer in making a better, more complete set of plans" (p.8). Estimates at this stage close the budget gap even further by providing even more accurate costs associated with a construction project and enables individuals to better understand costs associated with a particular project (Fatzinger, 2004).

A construction proposal contains a construction set of documents in which contractors and sub-contractors are capable of producing estimates in high detail and accuracy. Often a construction set of documents is required by local and state law showing the project will abide by all applicable codes. Construction documents contain accurately detailed sections, schedules, and specifications. Estimators are able to be highly thorough in their estimates and produce a cost in which they are able to submit as a proposal. Once an estimate is produced, general contractors can present a total project cost to the project's owner (Fatzinger, 2004).

Curriculum Development

As the construction industry becomes ever more reliant on technology, curriculum needs to be continuously adjusted to give students necessary skills to succeed in a working environment (McCade, 1995). Joseph McCade (1995) a professor of industry and technology at Millersville University stated: "(A) Secretary's Commission on Achieving Necessary Skills (SCANS) has issued a report entitled *What Work Requires of Schools*. The report finds considerable deficiencies among our youth, greater than half of whom leave school without the prerequisites to obtain a good job." (p. 2)

A 2000 report from The Secretary's Commission on Achieving Necessary Skills titled *What Work Requires of Schools* states there are five main competencies individuals must possess before entering a work environment. The report stated these as follows:

1. Resources: Identifies, organizes, plans, and allocates resources
2. Interpersonal: Works with others
3. Information: Acquires and uses information
4. Systems: Understands complex inter-relationships
5. Technology: Works with a variety of technologies

Further in a 2000 report titled *What Work Requires of Schools*, a three part foundation was established to display what skills are necessary to prosper in a post academic environment. The three part foundation is as follows:

1. Basic Skills: Reads, writes, performs arithmetic and mathematical operations, listens and speaks.

2. Thinking Skills: Thinks creatively, makes decisions, solves problems, visualizes, knows how to learn, and reasons.
3. Personal Qualities: Displays responsibility, self-esteem, sociability, self-management, and integrity and honesty.

These foundational skills are necessary for any individual entering a working environment and even more important in a construction due to necessary occupant safety. (The Secretary's Commission on Achieving Necessary Skills, 2000).

Many different ways are available to organize information and ideas in a technology-based curriculum development. Computer-based construction estimating software is based around a principle of communication technology systems curriculum approach. This method uses technology to gain relevant information in a short, almost instantaneous period of time. McCade (1995) stated "(Communication technology systems) reflect technology that involves the use of devices or methods to collect, process, store, or deliver information. Through electronic and graphic developments in communication, we have become a global society with the ability to interact instantaneously" (p. 4).

A major benefit of curriculum development is using learning modules to increase the degree of interactivity between instructors and students. It was found the use of incentives (in example: credit for completing modules was important to obtain quality work (Rouskas & Miller, 2007). Objectives of a technology based learning module by Rouskas et al. (2007) stated:

> Developing learning environment(s) that incorporate technology in the classroom is a challenging task. By adapting learning materials to use the technology, the instruction can provide a pedagogy utilizing more learning styles and provide an interactive

learning experience for each student. For instructors, we hope to raise awareness of how technology can be used in the classroom, support them in developing a new style of classroom learning environment, and provide them the means to move beyond (and "unlearn") the one-way communication typical of most college lectures. For students, we aim to provide a personalized learning experience with the classroom, improve student confidence with new learning, and convey to learners exactly what needs to be mastered (p. 3).

In order for a learning module to be all inclusive, Richardson et al. (1997) stated:

A typical module would include: a cover with title; a contents page; individual sections, with section dividers, each focusing on one component of the content; photographs in each section where appropriate, to provide a visual experience; fact sheets, pamphlets, bulletins, etc. for each section; and audiocassettes, if practical and appropriate, to explain each section.

Learning Modules can be difficult to create depending on course goals. Richardson and Bostick (1997) stated, "(By) keeping in mind the targeted audience, subject matter content, level of complexity, expense, and other considerations, a learning module can be simple or rather complex (p.28)". Input opportunities must be given to learners in order to fully support their learning experience

Typically, modules are capable of meeting the needs of a wide variety of subject matters and topics. As Richardson et al. (1997) declared, "Obviously, learning modules will not fit all subjects or clientele, but in reality, they can effectively cover a wide array of subjects if planned and developed correctly."

Summary

In order to gain knowledge of published information in the area of computer-based construction estimating, curriculum development, and Delphi studies, a review of literature was completed to better understand the depth of information available in the respective fields. A variety of sources was used to accurately survey information available in the related categories their respective categories.

During literature review, essential information was gathered that showed why a particular estimate is used during different stages of the construction process. Information obtained showed how estimates are essential tools that allow contractors to determine the size and scope of a project in the form of concrete material and financial data. This data is updated and modified continuously throughout a project to account for changes in design, material, cost, and schedule constraints.

A review of the Delphi study was undertaken in order to determine the breadth of knowledge available. Information was uncovered to show how a Delphi study enables a surveyor to obtain highly useful and open information from a variety of experts in a particular field. Delbecq, Van de Ven, and Gustafson (1975) showed the use of "systematic solicitation and collection of judgments on a particular topic" allows a surveyor to acquire highly productive information on a particular subject. Through a series of rounds, surveyors can acquire useful information from experts by facilitating discussion, contribution, and collaboration while maintaining a sense of anonymity (Shah, 2003).

To further supplement the overall goal of creating learning objectives for use in an academic environment, curriculum development was surveyed in order to create a foundation for information gained during this study. Information gathered showed the extent of creating a well-rounded learning module by taking into account variables unforeseen to curriculum development. Richardson and Bostick (1997) stated, "(By) keeping in mind the targeted audience, subject matter content, level of complexity, expense, and other considerations, a learning module can be simple or rather complex". Furthermore Richardson et al. (1997) showed that an effective learning module would contain a well crafted booklet that is well designed visually with information displayed in a systematic, cohesive manner.

The main goal of this review of literature was to determine existing understanding in acquiring learning objectives in the field of computer-based construction estimating. This basis was used later to compile essential learning objectives in order to create a computer-based construction estimating learning module.

CHAPTER III

METHODOLOGY

Computer-based construction estimating has quickly become standard practice with a vast majority of companies across various industries. Computer-based estimating software has become popular due to its accuracy, speed, reliability, and ease of use. Undergraduates preparing to enter a construction related career will greatly benefit from mastering procedures and techniques of computer-based construction estimating. The purpose of this study was to fill curriculum gaps within construction estimating courses at Eastern Illinois University.

This study was initiated by a graduate student in the area of technology management with a Bachelors of Science degree in Industrial Technology with a concentration in construction management. From a thorough review of literature focused on publications by Fatzinger, 2004, Holm, 2005, and Pratt, 2004, a set of competency areas were developed and presented to the Delphi panel during the initial round. This study focused on five main principles and techniques of computer-based construction estimating. An expert panel was established from individuals of academia and industry of which were nominated by persons from industry, research institutions, professional organizations, and academia. The study gathered learning objectives from these experts in order to establish a comprehensive list for further creation of a learning module related to computer-based construction estimating for undergraduate students to fill gaps in computer based estimating curriculum.

Delphi Study Techniques

Curriculum standards are often developed by an intra-university committee of professors and staff members, which limits the amount of expertise in a particular field. A

Delphi study is often used to expand a knowledge base by extending input to other experts in a particular field of interest. Moercke and Eika (2002) stated:

> The Delphi method uses iterated questionnaires distributed to an expert panel to reach a consensus or explore disagreements between the experts on a given topic. The questionnaire is changed between rounds to incorporate the answers given. The moderator who collects and analyses the responses knows the participants, but each expert's answers are anonymous to the rest of the panel and in publication. This has the advantage of enabling each participating expert to express view freely. (p. 472)

A Delphi method is often aimed to improve decision making in a group without having face-to-face interactions. Delbecq, Van de Ven, and Gustafson (1975) stated: "A Delphi study is a method of systematic solicitation and collection of judgments on a particular topic through a set of carefully designed sequential questionnaires, interspersed with summarized information and feedback of opinions derived from earlier responses" (p. 697).

Delphi studies often consist of a series of questionnaire rounds in which individuals participating are given a set of guidelines of which they are to adhere to. The Delphi process according Shah (2003) stated:

1. The first round of the questionnaire is characterized by exploration of the subject under discussion, wherein each individual contributes information he/she believes is pertinent.

2. The second round involves the process of reaching an understanding of how the group views the issue. Each expert receives a copy of the list and is asked to rate each item by the criterion of importance.
3. The third round of questionnaire includes the list and the ratings, indicates the consensus, if any, and asks the experts to revise their opinions.

Often little to no additional information is gathered using further rounds and often times is not advised due to limited amounts of relevant information (Ludwig, 1997).

Between rounds, results may need analysis in order to derive a definitive consensus agreement between the expert panel members. It is often important to look between rounds to determine whether the agreement remained throughout the study, or changed dramatically between rounds. Analysis can be used to determine if an expert panel changed their opinions as a result of the Delphi process rather than using their direct expert opinion (Greatorex & Dexter, 2000). Greatorex et al. (2000) stated that "additional information sheds light on the quality and reliability of the final decision, and is likely to lead to better decision making based on the expert panel's consensus" (p. 1020).

Several main disadvantages of Delphi studies according to Osborne, Collins, Racliffe, Millar, and Duschl (2003) were "the length of the process, researcher influence on the responses owing to particular question formulation, and difficulty in assessing and fully using the expertise of the group because they never meet" (p. 698). Another area of exploration regarding a Delphi study is participant drop out due to low motivation, study design or a multitude of other factors. These disadvantages are often negated due to the wide expertise acquired from the Delphi study through proper planning and coordination with the study participants.

Delphi Participants

Participants were nominated based on their expertise in the field of construction estimating along with proficiency in computer-based construction estimating software. Potential nominees were contacted via a large scale academia and industry listserv (Appendix A), where each individual was asked to respond no later than March 7th, 2008 with his or her willingness to participate, along with nominations of other qualified individuals. The following requirements were made regarding the research sample of this study:

1.) Experts practicing within industry estimating:

   d.) Had 3 or more years of experience closely working with Sage Timberline Office Estimating or any other computer-based estimating programs.

   e.) Had relevant experience in construction estimating and construction management processes.

   f.) Resides within the United States of America

2.) Academia

   d.) Graduate degree in a technology related field (Technology, Engineering, etc.)

   e.) Worked 5 or more years in an academic environment with a technology emphasis.

   f.) Resided within the United States of America

An engineering technology listserv was used as a starting point for nominating potential panel member. As of March 23, 2007, the listserv consisted of 3,806 members representing 870 institutions from 2 year to 4 year colleges, organizations, corporations and government agencies. Other contacts were made with Turner Construction Company of Chicago, as well as Hamann Construction Company of Manitowoc, Wisconsin.

Design of Delphi Study

Once six participants were identified, they were contacted via email, instructing them on the requirements of the study design. Once conformations were made, round one of the study was distributed to participants via email on March 19th, 2008.

Round one (Appendix B and Appendix C) asked each expert to write no less than five, but no more than eight learning objectives for five computer-based construction estimating categories. These categories asked for objectives in the areas of history and evolution of (a) computer estimates, (b) database creation, (c) takeoffs, (d) use of assemblies, and (e) report creation. Along with these five main categories, participants were given a blank sheet to input learning objectives they felt were important or necessary for undergraduate studies. Respondents were given nine days, between March 19th 2008 and March 28th, 2008, to complete a list of his or her essential objectives. From these responses, a questionnaire was formulated for use in round two.

Round two asked participants to rank the fifty-three learning objectives, tabulated from, round one on a floating scale with one being of least importance and seven being of most importance. This seven position scale was used to give participants adequate freedom to express their opinion on importance while limiting the possible statistical variability of a larger scale would be used. The fifty three responses were placed in their respective five categories of (a) history and evolution of computer estimates; (b) database creation; (c) takeoffs; (d) use of assemblies; (e) report creation, along with an extra category featuring miscellaneous items that could not be placed into a specific category. Participants were sent a non-disclosing email which listed all expert responses from round one, and were then given eighteen days to complete rank response sheets and return via email. Upon completion of the eighteen day period, two members were non-responsive and eliminated from the survey. Once these results were quantified a set of essential learning objectives were established for creating a computer-based construction estimating module.

Summary

The objective of this study was to find learning objectives necessary for fundamental knowledge and skills of computer-based estimating programs. Once objectives were determined, a learning module can be created specifically for software and institutional goals to effectively educate students on important computer-based estimating skills. Expert input on these objectives allowed undergraduate students to learn only necessary and essential skills which in return will allow them to excel in a construction estimating environment upon graduation.

The study used willing experts nominated from both academia and industry to compile a set of learning objectives for construction estimating personnel. Through several rounds of surveys, panel members were allowed to input objectives they felt were important to individuals participating in computer-based construction estimating. Once objectives were obtained, they ranked fellow expert responses on a floating scale of one to seven, thus creating essential learning objectives for creation of an instructional module. This process followed a slightly modified Delphi study technique, in which two rounds of questionnaires were used, in order to accurately acquire essential learning objectives. Data from the surveys will be analyzed based on the conformance to other members responses, with objectives scoring five or higher of most essential to a computer based construction estimating learning environment.

CHAPTER IV

RESULTS

The purpose of this study was to create a set of learning objectives derived from an expert panel of individuals involved in both academia and industry within the field of computer-based construction estimating. Through several rounds of a modified Delphi study, an expert panel provided their learning objectives in hopes of creating a learning module geared towards giving undergraduates the necessary knowledge and skills to succeed in the construction field.

This study will search for an answer to the following question; Which knowledge and skills are most important to recent graduates entering the field of computer-based construction estimating?

Description of Expert Panel

A panel of six experts selected from a combination of nominations and industry personnel through email contacts and personal correspondence over a period of several months. Through an electronic listserv, a notification email was sent to over approximately 3,800 members from both academic and industry fields.

In order to allow for academic freedom, individuals were not made aware of fellow committee members' participation throughout this study. To ensure their identities were not revealed to fellow committee members, all electronic mail messages were sent using the blind carbon copy (bcc) feature. The expert panel members' identity will therefore not be disclosed in discussion of their ideas or opinions, for those reason members will only be referenced as member "A", member "B", etcetera for the remainder of this study.

All the members were nominated and chosen based on their experience in both academia and/or industry in the field of computer-based construction estimating. In the following respondent descriptions, letters are used to denote different respondents to the survey. These letters are used to conceal their identity, while showing their respective experience. Use of these letters is used to further show responses in tables showing how a particular individual responded to survey questions.

Member "A" has more than three years of estimating experience in various size construction projects with a large general contractor within the United States.

Member "B" has more than thirteen years of experience in the construction industry in the areas of project engineer, chief scheduler and estimator, and vice president of a contracting firm. In addition member "B" has been teaching estimating courses at the collegiate level for two years.

Member "C" has more than fifteen years' experience within the construction industry in the fields of accounting, finance, and estimating. Member "C" has also been teaching collegiate level estimating and other related construction accounting courses for more than nine years.

Member "D" has more than twenty seven years of construction related experience in which member "D" spent time as an estimator with experience in Timberline, MC2 and Microsoft Excel based construction estimating. Member "D" has more than two years of experience as a college professor of which member two instructed students on Timberline, MC2 and Microsoft Excel based computer-based construction estimating.

Member "E" has more than twenty five years of construction related experience in the fields of tradesmen, architectural and engineering design, as well as project management.

Member "E" furthermore has more than seven years experience as a college professor in the fields of estimating, scheduling, personnel management, and student internship development.

Member "F" has more than eight years of college teaching experience in the field construction computer applications. Member "F" industry experience was not able to be verified.

Expert Panel Opinions

The following results gathered in this study are the opinions of four out of six expert panel members' and their thoughts as to what are important learning objectives for individuals participating in computer-based construction estimating courses. These experts were derived from an academic and industry listserv as well as personal requests to industry personnel.

Once expert panel members agreed to participate in the study, they were distributed round one (Appendix B) of the study and were asked to complete the areas outlined. Round one was distributed and asked expert members to input their opinions as to the best possible learning objectives in the fields of; history and evolution of computer estimates, database creation, takeoffs, and use of assemblies, report creation and a blank category for their personal opinions on learning objectives.

In the first round of gathering learning objectives, two panel members did not respond due to time constraints. Of the four members that responded, a preliminary list of learning objectives was complied. With the responses compiled in round one, information acquired was used to assist in creating round two of the study.

During round two of the study, experts were asked to rank the responses of round one learning objectives on a floating scale. Use of a floating scale enabled experts to share their opinion by weighing provided responses based on their perceived importance. The floating scale was based on a numbering system in which one (1) was of least importance and seven (7) was of most importance. Remaining options of two (2), three (3), four (4), five (5) and six (6) allowed experts to display their implied importance of a particular learning objective by using a methodical range exhibiting their opinion.

The compiled results of round one were distributed to the entire original field of six experts with four individuals responding to round two of the Delphi survey. After results of the second round were compiled it was determined a third round survey was unnecessary due to the quality of information received in the first two rounds.

Table 1 *Category 1 History and Evolution of Computer Estimates*

	1	2	3	4	5	6	7
• Explain how construction companies create computer programs for their own use				A D	C	B	
• Explain and show how construction companies adapt spreadsheets for their own use				D	A B C		
• Discuss how commercial estimating programs have become available		C		A B D			
• Discuss court cases against software companies for estimating errors caused by software malfunctions	C	A			D		B
• Discuss advantages and disadvantages of computer estimating						A B	C D
• History is not important and should be disregarded in developing curriculum	B C	A	D				

As shown in Table 1, history and evolution of computer estimates, several topics were considered relevant while other categories were of less relevance. In explaining how construction companies create computer estimating programs for their own use, respondents determined that this result was of some importance with a composite average of 4.75 out of seven. When showing how to adapt spreadsheets for their own use, the expert panel also determined that this was of some importance with a composite average of 4.75. Discussion of how commercial estimating programs have become available was of some importance with an average of 3.50. Acquiring a composite average result of 3.75 was the discussion of court cases against software companies for estimating errors caused by software malfunctions. On the other hand dialogue in the field of advantages and disadvantages of computer estimating averaged 6.50 on a scale of seven. Finally respondents stated that history should not be ignored with a composite average of 1.75.

Table 2, database creation, was used to show how category 2; database creation, responses were represented by the expert panel. Understanding derivation of unit costs for labor, materials, equipment, and subcontractors was determined to average 6.75 on a scale of seven. Including equipment costs along with small tools and supplies into an estimate had an average response of 6.50 from the panel. Deriving of productivity factors from the empirical method resulted in the average response of 6.00. Furthermore, the application of skills to derive total unit costs was determined to have an average response of 5.75 on a scale of seven. Work Breakdown Structure (WBS) codes used to breakdown and organize a database received a common response of 4.00. Application of a variety of wage rates for different jobs when using open shop, union, or prevailing wages was determined to rate a 6.00 on a scale of seven.

When using a database to aid in takeoffs, panel members found 5.25 to be the mean response. An understanding of the inherent errors that may occur using unit priced estimating averaged 6.25 between responding expert members. The skill set of creating new databases, along with copying an existing database was firmly a 5.75 among expert respondents. Set up and applying productivity rates for each item used in an estimate received a 6.25 average from panel members. Panel members established a 6.50 mean for individuals to learn how to create formulas to convert takeoff dimensions to formulate bid quantities. The final learning objective of understanding current market prices and conditions when creating and using databases was given a 6.25 average on a scale of seven for database creation.

Table 2 *Category 2 Database Creation*

	1	2	3	4	5	6	7
• Understanding derivation of unit costs for labor, materials, equipment, and subcontractors						A	B C D
• Discussion of equipment costs (i.e. Fuel, oil, grease, tires / tracks, maintenance) along with small tools and supplies (i.e. Hammers, etc)					A		B C D
• Derivation of productivity factors by empirical method				A		C	B D
• Applying skills to derive total unit cost			A			C	B D
• WBS (Work Breakdown Structure) Code to breakdown and organize database	B			C	A	D	
• Applying different wage rates (i.e. Union, open shop, prevailing wage rates)					B	A C	D
• Use of database to help with takeoffs					A,B C	D	
• Understanding inherent errors that may occur using unit price estimating (Oversimplification of quantities, not applying differing productivities based on specific jobsite requirements)					A	B	C D
• Ability to create a new database as well as copy an existing database for use				A	C		B D
• Set-Up and apply productivity rates for each item					A	C	B D
• Ability to create formulas to convert takeoff dimensions to formulate bid quantities					A		B C D

Table 3, takeoffs, was used to show importance of learning objectives in the field of taking off quantities from construction documents. Results shown in Table 3 tabulate the expert panel's opinions in regards to the underlying learning objectives. The overall category received a composite average of 5.77 on a scale of seven. An ability of learners to understand units associated with takeoff items was given a 6.50 average response among the responding panel members. Understanding basic geometry received a mean score of 6.00. The ability to complete simple take offs of isolated portions of work scored a 5.75 among the panel.

Table 3 *Takeoff's*

	1	2	3	4	5	6	7
• Ability to understand units associated with items during a takeoff (i.e.. Earthwork (cy), fine grade (sy), Lumber (mbf), etc						A C	B D
• Understanding basic geometry				A		C	B D
• Completing of simple take-offs of isolated portions of work				A	C		B D
• Preparing a takeoff in which other can easily understand					C		A B D
• Comparing take-offs with others to ensure quality and quantity are accurate				C	A	B	
• Students should be able to takeoff single items using a database					A	D	B C
• Students should be able to takeoff assemblies using a database					A	B C,D	
• Student should be able to modify assemblies while completing take-off without changing database				A	B C,D		
• Student should be able to takeoff items not present in a database					A C		B D
• Ability of students to takeoff items manually and apply them into an estimating program				A		C	B D
• Discuss advantages and disadvantages of electronic take offs						A B,D	C
• Discuss and apply certain shortcuts when completing take off (repetitive items)				C	A D	B	
• Explain / demonstrate different tools for take-offs (i.e. digitizer, on screen take off, etc)				C	D	A B	

Preparation of takeoffs that one can easily understand was rated 6.50. Comparison of takeoffs with others to ensure quality and quantity was given an average score of 5.00 on the scale of one to seven. When deciding if students should be able to takeoff single items using a database, respondents scored a 6.25 average. Another surveyed category asked if students should be able to modify assemblies while completing takeoffs without changing the base database attained a 4.75. The survey moreover asked experts if students should be able to takeoff items not present in a database in which they gave an average response of 6.00. Surveyed experts decided to give an average response of 6.00 to the question of student's ability to takeoff items manually and apply them into an estimating program. The expert panel was further asked to rank discussing advantages and disadvantages of electronic take offs, in which they gave a common response of 6.25. Discussing and applying certain shortcuts when completing take off (repetitive items) scored an average of 5.00 on the scale of seven. Finally, explanation and demonstration of different take off tools for take-off (i.e. digitizer, on screen take off, etc) received a mean response of 5.25.

In Table 4, Use of Assemblies, the expert panel was asked to rank several learning objectives as the related to using assemblies in computer-based construction estimating programs. The first learning objective of discussing advantages and disadvantages of assembly usage received an average response of 6.25 on the scale of one to seven. When asked of the importance of combining related WBS (work breakdown structure) items together to make common items faster to take off, respondents presented a score of 5.00. The expert panel was then asked to rank importance of students being able to identify all of the components needed to create an assembly, which they scored it to be 5.50. Scoring 5.25 among the expert panel was if students should be able to set up an assembly in the database.

When asked if students should be able to build logic into their assembly, surveyed individuals answered with an average tally of 5.00. Surveyed individuals were asked to judge the importance of students' ability to apply different formulas to each item of the assembly if necessary in which they gave a response of 5.25.

Table 4 *Use of Assemblies*

	1	2	3	4	5	6	7
• Advantages and Disadvantages of assembly usage					A	B	C,D
• Combine related WBS together to make common item take off faster				B	A,C	D	
• Student should be able to identify all of the components needed to create an assembly				A,B			C,D
• Student should be able to set up an assembly in the database				A,B		C	D
• Student should be able to build logic (choices between materials) into the assembly			B	A		D	C
• Student should be able to apply different formulas to each item of the assembly if necessary			A	B			C,D

Table 5, Report Creation, experts were solicited to rank learning objectives in regards to the importance of students learning essential elements of creating usable reports. First, the panel was asked the importance of being able to report estimated overhead, profit, bond, and insurance with a determined average of 5.50. Next, the panel was surveyed to check significance of students being able to create a materials list from an estimate, in which they gave an average rejoinder of 4.25. When creating unit price estimates, respondents decided an average of 4.75. A score of 4.75 was also give to the learning objective of students being able to complete standard bid documents such as bonds, non-collusive affidavit, etc.

Table 5 *Report Creation*

	1	2	3	4	5	6	7
• Report with estimated overhead, profit, bond, and insurance				C	A	B	D
• Create materials list from estimate				A C,D	B		
• Creating Unit Price estimates			A	C		B,D	
• Ability of student to complete standard bid documents (bonds, non-collusive affidavit, etc)			C	A		B,D	
• Student should be able to print detailed estimate with information relevant to client			C			A,B	D
• Student should be able to print a report with a summary estimate sorted by cost code			C		A		B,D
• Student should be able to print a materials report for a bid			C	A		B,D	
• Student should be able to print a detailed estimate with add-ons allocated		C			A	B,D	

Surveyed experts also decided students should be able to print detailed estimates with information relevant to a client with a score of 5.50. When questioned about a student's ability to print a report with a summary estimate based by cost code, experts gave an average response of 5.50. An average response of 4.75 was obtained in regards to students' ability to print a materials report for a bid. Furthermore, respondents bestowed an average response of 4.75 to a student's ability to print a detailed estimate with add-ons allocated. Lastly, experts decided that students should be able to convey to clients what you what them to know with the average response of 6.75 on a scale of seven.

The final table, Table 6, represents miscellaneous items acquired through input from the expert panel. These items were determined to be important to a particular individual being surveyed but did not fit into a particular category. First a student should be able to work with a team using real plans and specs to produce an estimate received a 6.50 score. Incorporating sub quotes for a project with all subs and no self-preformed work scored 6.25. Students' ability to incorporate add-ons into a bid received an average response of 6.25. Being able to check for errors in a bid garnered a 6.75 average response. Being able to set up a new estimate from scratch received a 5.75 response. Discussion of field experience when creating an estimate established a response of 6.00. To conclude, the expert panel decided that discussing how each contractor does estimating differently received an average response of 6.25.

Table 6 *Miscellaneous Learning Objectives*

	1	2	3	4	5	6	7
• Student should work with a team on a project using real plans and specs to produce an estimate					D		A B,C
• Incorporating sub-quotes for a project with all subs						A B,C	D
• Student should be able to incorporate add-ons into a bid					A	B C,D	
• Student should be able to check a bid for errors						B	A C,D
• Student should be able to set-up a new estimate from scratch				A		B,C	D
• Discuss importance of field experience when creating an estimate					C	A,B	D
• Discuss how each contractor does estimating different					C	A	B,D

In all, twenty four learning objectives were derived from round two of the study. In the category of History and Evolution of Computer Estimates, the expert panel declared two learning objectives of particular importance; explain and show how construction companies adapt spreadsheets for their own use along with discussing advantages and disadvantages of computer estimating. The category of database creation established six learning objectives pertinent to setting up a computer estimating database; understanding derivation of unit costs for labor, materials, equipment; discussion of equipment costs (i.e. fuel, oil, grease, tires, tracks, maintenance) along with small tools (i.e. hammers, drills, maintenance); understand inherent errors that may occur using unit price estimating plus oversimplification of quantities, and productivity rates based on jobsite requirements may cause inaccurate prices; being able to set up and apply productivity rates for each item in a product; have the ability to create formulas in which the estimator can convert takeoff dimensions into usable bid quantities. In the field of Takeoff's, five objectives were proven; students should have the ability to understand units associated with particular items in a takeoff. In example earthwork uses cubic yards (cy), fine grading uses square yards (sy), and lumber is measured in MBF (one thousand board feet); students should be able to prepare a takeoff that is easy to interrupt and understand by other team members; students should be able to take off items not present in a database; students should be able to take off items manually or by hand, and apply their findings to a computer estimate; students should understand the advantages and disadvantages of computer-based estimates. Use of assemblies

Table 7 is used to show the appropriate learning objectives derived from expert input. Six categories were used to properly display the learning objectives in their appropriate fields. In history and evolution of computer estimates, the expert panel determined it was important to explain and show how construction companies adapt spreadsheets for their own use along with discussing the advantages and disadvantages of computer estimation. For database creation, understanding the derivation of unit costs for labor, materials, equipment, along with discussion of equipment and small tool costs were additionally perceived as important objectives. Additional abilities were included to being able to understand inherent errors that may occur when using unit price estimating, such as oversimplification of quantities and productivity rates based on jobsite requirements may cause inaccurate prices. Experts further relayed the importance of being able to set up and apply productivity rates for each item in a product as well as creating formulas in which the estimator can convert takeoff dimensions into usable bid quantities while understanding how current and future market prices may impact the costs associated with a project in the form of escalation.

Another important aspect of computer based estimating is the proper use of takeoffs to properly compile quantities associated with a particular estimate. The panel concluded that five topics were of relevant use and information. It was determined the proper use of industry standard quantities was of importance when taking off a particular portion of work. Panel members relayed the importance of clear and concise takeoff organization in which any member of the team can easily read and interrupt the quantities gathered. Students would further need to be able to take off items that were not easily assigned to a pre-determined database in respect to pricing. Manual take off, or the process of acquiring useful quantities and pricing without the use of a technological aid was further important to becoming proficient in computer based estimating. The final learning objective established for take-offs was the ability to show learners the advantages and disadvantages of using a computer based estimating program.

Use of assemblies was a category in which experts established three learning objectives for a computer based learning experience. An important aspect was for learners to understand the distinct advantages and disadvantages of using assemblies to compile a detailed estimate. When using assemblies, learners will be able to identify and compile necessary components to establish a complete and accurate assembly for use in the estimate. When using assemblies in computer based estimates, learners would be able to incorporate logic to accurately capture differences within the assembly that occur on specific projects.

In order to easily display useful information to members involved in an estimate, panel members derived three learning objectives for further consideration. Item one displayed the need to accurately display the project cost as well as overhead, profit, bond, and insurance in an easy to identify format. In a second objective, learners would be able to display an estimate report in a manner that would best suit a client's needs. A third and final objective was to sort and print an estimate in a format consistent with their representative cost code.

A final category of miscellaneous was used for panel members to establish learning objectives that did not fit into any of the supplementary categories. The first of five objectives outlined was the ability of a learner to work in a team environment to create and publish a complete estimate. When working on an estimate, learners would be able to incorporate subcontractor pricing as needed to compile an all-inclusive estimate. When verifying the completeness and accuracy of an estimate, learners will be capable of cross checking numbers and data to ensure accuracy. Learners will need to understand the importance of incorporating real work knowledge into an estimate in order to ensure accuracy and relevance to a specific project's requirements. In order to show different applications of estimates, learners will need to understand the different estimating techniques used amongst different companies, trades, and locations in order accurately reflect market conditions.

Table 7 *Appropriate Learning Objectives*

Category	Learning Objective
History and Evolution of Computer Estimates	a.) Explain and show how construction companies adapt spreadsheets for their own use b.) Discuss advantages and disadvantages of computer estimating
Database Creation	a.) Understand derivation of unit costs for labor, materials, equipment b.) Discussion of equipment costs (i.e. fuel, oil, grease, tires, tracks, maintenance) along with small tools (i.e. hammers, drills, maintenance) c.) Understand inherent errors that may occur using unit price estimating. Oversimplification of quantities, and productivity rates based on jobsite requirements may cause inaccurate prices d.) Being able to set up and apply productivity rates for each item in a product e.) Have the ability to create formulas in which the estimator can convert takeoff dimensions into usable bid quantities f.) Understand how current and future market prices may impact the costs associated with a project.
Takeoffs	a.) Students should have the ability to understand units associated with particular items in a takeoff. In example earthwork uses cubic yards (cy), fine grading uses square yards (sy), and lumber is measured in MBF (one thousand board feet) b.) Students should be able to prepare a takeoff that is easy to interrupt and understand by other team members c.) Students should be able to take off items not present in a database d.) Students should be able to take off items manually or by hand, and apply their findings to a computer estimate e.) Students should understand the advantages and disadvantages of computer-based estimates
Use of Assemblies	a.) Students should have an understanding of the advantages and disadvantages of using assemblies to compile an estimate b.) Students should be able to identify all components necessary to create a new assembly from scratch c.) Students should be able to build logic into their assemblies, or have choices of different materials depending on project specifics.
Report Creation	a.) Students should be able to create an estimate report with overhead, profit, bond, and insurance clearly identified b.) Students should be able organize a report in a manner that is most relevant to a client's needs c.) Students should be able to print an estimate report with items sorted by their specific cost code
Miscellaneous	a.) Students should work with a team, on a real world sample project, using all necessary documents to compile an estimate. b.) Students should be able to incorporate subcontractor prices into an estimate they are working on c.) Students should be able to quickly review an estimate for errors that may occurred when tabulating results d.) Students should be exposed to real world field examples of construction in order to best understand how field processes impact estimates e.) Students should be able to understand how different companies, trades, etc estimate differently based on a variety of factors

Summary

In all, fifty three learning objectives were acquired from a two round modified Delphi study. These fifty three objectives were derived from round one of the study in which the expert panel submitted their most essential learning objectives for six pre-determined categories. Based on ranked responses, appropriate learning objectives were determined for each respective category and compiled in twenty four learning objectives.

During round two of this study, experts were able to rank the compiled fifty three responses on a scale from one to seven with one of least importance and seven of most importance. The results of this two round Delphi study assisted in determining which learning objectives are of most importance to students studying computer-based construction estimating at an undergraduate level. From these responses, twenty four were determined to be of high significance and considered appropriate learning objectives. These objectives were determined to be of importance for their usefulness in real world applications when estimating complex projects for dissimilar industries, trades, and regions.

CHAPTER V

CONCLUSION

Computer-based construction estimating has become the industry standard in terms of accurately and quickly organizing specified costs associated with a construction project. Holm (2005) stated the importance of cost estimating by stating, "(Construction) cost estimating involves collecting, analyzing, and summarizing all available data pertaining to a project". When sorting through information for a project, it is essential to give estimators the necessary tools to calculate and tabulate results into coherent and constructive data.

This study focused on generating learning objectives in six categories of practical and essential principles for computer-based construction estimating. Establishing an expert panel of members was accomplished to administer the Delphi style study. The first round of this study was electronically emailed to committed members for them to input five learning objectives they found essential for each of the six main categories. Upon acquiring the expert panel members' opinions, a second round was sent requesting remaining members to rank the compiled responses on a floating scale in which one was of least importance and seven was of most importance. Once the final results were tallied, learning objectives can be created that best educate individuals completing undergraduate level coursework in the area of construction estimating.

Research Questions

Overall this study was geared to answer the following question: What computer-based estimating learning objectives are of most significance for undergraduate college students entering the construction industry upon graduation? A Delphi study was used to survey experts in the field of computer-based construction estimating as to their interpretation of essential learning objectives for new hires in the construction industry. Use of the learning objectives acquired during this study will, in the opinion of the researcher, enable alumni of an undergraduate program to excel in an entry level construction estimating position.

Appropriate Learning Objectives

Through data acquired researching computer-based estimating, the researcher was able to establish twenty four learning objectives as essential to undergraduate coursework. All of the obtained twenty four learning objectives scored above a five on the scale of seven for importance. Though many more than twenty four items scored above a five in this study, the researcher decided these particular twenty four as essential learning objectives for undergraduate studies.

Using the Delphi study technique allowed the researcher to seek advice from industry and academic experts while refraining from damaging collusion. The Delphi study further allowed the researcher to acquire unbiased responses that were essential to creating a list of learning objectives most beneficial to undergraduate students. Though only a small number of participants were used in this study, the researcher feels results gained were of similar quality and relevancy to that of a larger survey group. A larger survey population may have established more learning objectives that might have been useful to this study. Furthermore, only using two rounds was not only a complete and precise way to gather information, it enabled the researcher to gain data in a very efficient manner.

Learning objectives established in this study are to help in the creation of comprehensive learning modules for undergraduate computer-based construction estimating.

With many other technologies computer-based estimating has become an essential tool that enables users to complete tasks in a more efficient and economical manner.

Recommendations

Information obtained in this study led to the following recommendations for further study and research. With the continuing improvement of computer hardware and software, appropriate learning objectives can be continuously updated. Future studies in computer-based estimating should be focused on how software and tools can make estimating easier to complete and understand. Further research can be used to accumulate learning objectives from this study into useful learning modules for daily classroom use. Another topic of research should be to determine how to best present computer-based estimating modules, whether this be in an instructor-led venue or allowing learners to use computer learning modules to further understand estimating. These findings can further be studied to compare current and past construction estimating curriculum to determine trends in educational delivery methods and explore the best methods for implementing these learning objectives. Expanding on exploring curriculum, supplementary research may be completed in comparing these findings with current curriculum offerings to determine overlaps, and additional gaps that may exist in the knowledge pool.

Additional ramifications may include micro studies on particular learning objectives to determine if sub learning objectives for a particular item are possible. This may include determining if the learning objective is down into it purest sense, and no other skills can be derived from a particular objective.

This is only a short list of ideas for future research and should not limit the possibilities of research in additional sectors of computer-based estimating. Another recommendation of further study would be to test the 24 learning objectives derived for additional supporting information that may further expand on the already acquired knowledge.

REFERENCE

Delbecq, A., Van de Ven, A., & Gustafson, D. (1975). *Group techniques for program planning.* Glenview, IL: Scott Foreman.

Fatzinger, J. A. (2004). *Basic Estimating for Construction* (2nd Edition ed.). Columbus, Ohio: Pearson Prentice Hall.

Greatorex, J., & Dexter, T. (2000). An accessible analytical approach for investigating what happens between the rounds of a Delphi study. *Journal of Advanced Nursing*, 1016-1024.

Hendrickson, C. (2003). *Project Management for Construction.* Pittsuburgh, PA: Prentice Hall.

Holm, L., Schaufelberger, J. E., Griffin, D., & Cole, T. (2005). *Construction Cost Estimating Process and Practices.* Columbus, Ohio: Pearson Prentice Hall.

Ludwig, B. (1997, October). *Predicting the Future: Have you considered using the Delphi Methodology?* Retrieved June 2, 2008, from Journal of Extension: http://www.joe.org/joe/1997october/tt2.html

McCade, J. M. (1995, November). Resources for Developing Technology Education Curriculum. *Tech Directions*, 55.

Moercke, A. M., & Eika, B. (2002). What are the clinical levels of newly graduated physicians? Self-assessment study of an intended curriculum identified by a Delphi process. *Medical Education*, 472-478.

Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What "Ideas-about-Science" Should Be Taught in School Science? A Delphi Study of the Expert Community. *Journal of Research in Science Teaching*, 692-720.

Pratt, J. D. (2004). *Fundamentals of Construction Estimating* (2nd Edition ed.). Clifton, New York, United States: Thomson Delmar Learning.

Richardson, J. G., & Bostick, G. W. (1997, May 15). *Developing Learning Modules.* Retrieved June 2, 2008, from NC State University Department of Agricultural Extension Education: http://www.ces.ncsu.edu/AboutCES/Factsheets/develop.html

Rouskas, G. N., & Miller, C. S. (2007). *Learning with In-Class Technology: The 15-Minute Learning Module Approach.* Raleigh, NC: Department of Computer Science, North Carolina State University.

Sage Software. (2007). *Estimating Fundamentals.* Newcastle, United Kingdom: Sage Software.

Shah, H. A. (2003). *Results of the Eastern Michigan University Delphi Study on Engineering Management Masters' Program Curriculum.* St Louis, MO: 24th American Society for Engineering Management National Conference.

The Secretary's Commission on Achieving Necessary Skills. (2000). *What Work Requires of Schools.* Washington, DC: US Department of Labor.

United States Department of Energy. (1997, March 28). *DOE Directives Regulations and Standards.* Retrieved June 2, 2008, from United States Department of Energy: http://www.directives.doe.gov/pdfs/doe/doetext/neword/430/g4301-1chp4.pdf

APPENDICES

Appendix A

Dear Academia and Industrial Personnel,

As young construction professionals leave college and enter the construction workforce, a multitude of tools and resources are needed in order to be successful construction estimators. Often the more construction related experiences individuals are exposed to prior to employment, the more successful and beneficial that person will be in a new career.

Eastern Illinois University strives to prepare students for successful careers in many different technological fields. Staying current on technology and other trends allow students the opportunity to excel as soon as they enter the construction industry. Currently Eastern Illinois University lacks a computer-based estimating program to supplement their construction curriculum. The question then arises if we should incorporate a computer-based estimating programs into the curriculum and if so which learning objectives would we like to achieve?

As a result, several individuals at Eastern Illinois University are doing research to determine learning objectives for a computer estimating program based learning modules. These learning objectives would assist in creating an instructional module for undergraduate students studying construction management within the Industrial Technology program. In order to create this curriculum, we have chosen to use the Delphi study technique in which a panel of experts would provide feedback essential to forming this curriculum base. If you or someone you know meets either of the following criteria, we would ask you to respond by Friday March 7th, 2008 by emailing contact information to Ryan Schulz at the address listed below. Your help is greatly appreciated for furthering of this study, and the enhancement and quality of undergraduate studies in the future.

Criteria

1. Industry
   a. Has 3 or more years of experience closely working with Sage Timberline Office Estimating or any other computer-based estimating programs.
   b. Has relevant experience in construction estimating and construction management processes.
   c. Resides within the United States of America
2. Academia
   a. Graduate degree in a technology related field (i.e. Technology, Engineering, etc.)
   b. 5 or more years working in an academic environment with a technology emphasis.
   c. Resides within the United States of America

Thank you for your time and effort,

Ryan J. Schulz
Construction Research Assistant
Eastern Illinois University
rjschulz@eiu.edu
(920)323-6570

Dr. David W. Melton
Assistant Professor
Eastern Illinois University
dwmelton@eiu.edu
(217)581-5762

Appendix B

March 19th, 2008

Dear Academia and Industry Personnel,

Thank you for your participation in Eastern Illinois University's computer-based construction estimating Delphi study. Enclosed is Round 1 of a 2 round study on setting objectives for particular topics of construction estimating.

In the form below you will see five main topics (History and Evolution of Computer Estimates, Database Creation, Takeoffs, Use of Assemblies, Report Creation) in which you will input the most important learning objectives to be covered for each. There is also a blank sheet in which you may input a main topic you feel important for undergraduate students to learn. Please include at least five learning objectives under each while not using more than eight. Include what the learner is currently able to understand, important conditions under which the performance is expected to occur, and quality or level of performance considered acceptable.

Type your responses directly in the form and email results to Ryan Schulz at the address listed below **<u>no later than Friday March 28th, 2008.</u>**

Thanks again for your time and effort in this study,

Ryan J. Schulz
Construction Research Assistant
Eastern Illinois University
rjschulz@eiu.edu
(920)323-6570

Dr. David W. Melton
Assistant Professor
Eastern Illinois University
dwmelton@eiu.edu
(217)581-5762

Appendix C

Computer-based Estimating Delphi Round 1

Eastern Illinois University

1.) History and Evolution of Computer Estimates

1.)
2.)
3.)
4.)
5.)
6.)
7.)
8.)

2.) Database Creation

1.)
2.)
3.)
4.)
5.)
6.)
7.)
8.)

3.) Takeoffs

1.)
2.)
3.)
4.)
5.)
6.)
7.)
8.)

4.) Use of Assemblies

1.)
2.)
3.)
4.)
5.)
6.)
7.)

8.)

5.) Report Creation

1.)
2.)
3.)
4.)
5.)
6.)
7.)
8.)

Topic:______________________

1.)
2.)
3.)
4.)
5.)
6.)
7.)
8.)

Appendix D

Construction Estimating Software Delphi Instrument – Round Two

May 5, 2008

Dear Industry and Academia Personnel,

Thanks to everyone for participating in Round One for the computer-based estimating software curriculum development. This round consists of objectives, attached as an excel document, compiled from the previous round to create a ranking system for importance of each objective. Rank the objective on a scale ranging from 1 as least importance and 7 as most importance by placing an 'x' in the appropriate box. If you did not respond with information in previous rounds, please feel free to complete this round and input additional objectives at the end of the response sheet. Please email your response to Ryan Schulz (rjschulz@eiu.edu) NO LATER THAN May 23rd, 2008.

Thanks again for you time and effort on the subject matter and hope to hear from you soon!

Thank You,

Ryan Schulz, B.S.
Eastern Illinois University
School of Technology

Appendix E

	Least Important					Most Important	
	1	2	3	4	5	6	7
EXAMPLE				X			

Category 1 History and Evolution of Computer Estimates	1	2	3	4	5	6	7
Explain how construction companies create computer programs for their own use							
Explain and show how construction companies adapt spreadsheets for their own use							
Discuss how commercial estimating programs have become available							
Discuss court cases against software companies for estimating errors caused by software malfunctions							
Discuss advantages and disadvantages of computer estimating							
History is not important and should be disregarded in developing curriculum							

Category 2 Database Creation	1	2	3	4	5	6	7
Understanding derivation of unit costs for labor, materials, equipment, and subcontractors							
Discussion of equipment costs (i.e.. Fuel, oil, grease, tires / tracks, maintenance) along with small tools and supplies (i.e.. Hammers, etc)							
Derivation of productivity factors by empirical method							
Applying skills to derive total unit cost							
WBS (Work Breakdown Structure) Code to breakdown and organize database							
Applying different wage rates: (i.e.. Union, open shop, prevailing wage rates)							
Use of database to help with takeoffs							
Understanding inherent errors that may occur using unit price estimating (Oversimplification of quantities, not applying differing productivities based on specific jobsite requirements							
Ability to create a new database as well as copy an existing database for use							
Set-up and apply productivity rates for each item							
Ability to create formulas to convert takeoff dimensions to formulate bid quantities							
Understand current market prices and conditions when creating and using databases							

Category 3 Takeoffs	1	2	3	4	5	6	7
Ability to understand units associated with items during a takeoff (i.e.. Earthwork (cy), fine grade (sy), lumber (mbf) etc.)							
Understanding of basic geometry							
Completing of simple take-offs of isolated portions of work							
Preparing a takeoff in which others can easily understand							
Comparing take-offs with others to ensure quality and quantity are accurate.							
Students should be able to takeoff single items using a database							
Students should be able to takeoff assemblies using a database							
Student should be able to modify assemblies while completing take-off without changing database							
Student should be able to takeoff items not present in a database							
Ability of Students to takeoff items manually and apply them into an estimating program							
Discuss advantages and disadvantages of electronic takes offs							
Discuss and apply certain shortcuts when completing take off (repetitive items)							
Explain / demonstrate different tools for take-off's (i.e.. Digitizer, on screen take-off, etc)							

Category 5 Report Creation	1	2	3	4	5	6	7
Report with estimated overhead, profit, bond, and insurance added							
Create materials list from estimate							
Creating Unit Price estimates							
Ability of student to complete standard bid documents (bonds, non-collusive affidavit, etc)							
Student should be able to print a detailed estimate with information relevant for client							
Student should be able to print a report with a summary estimate sorted by cost code							
Student should be able to print a materials report for a bid							
Student should be able to print a detailed estimate with add-ons allocated							
Convey to your client what you want them to know							

Miscellaneous Items	1	2	3	4	5	6	7
Student should work with a tem on a project using real plans and specs to produce an estimate							
Incorporating sub-quotes for a project with all subs							
Student should be able to incorporate add-ons into a bid							
Student should be able to check a bid for errors							
Student should be able to set-up a new estimate from scratch							
Discuss importance of field experience when creating an estimate							
Discuss how each contractor does estimating different							

Additional Items (Please add items you feel fit along with a ranking)	1	2	3	4	5	6	7

Appendix F
Compilation of Round 2 Expert Panel Opinions

Category 1 History and Evolution of Computer Estimates	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Explain how construction companies create computer programs for their own use				**A,D**	**C**	**B**	
Explain and show how construction companies adapt spreadsheets for their own use				**D**	**A,B,C**		
Discuss how commercial estimating programs have become available		**C**		**A,B,D**			
Discuss court cases against software companies for estimating errors caused by software malfunctions	**C**	**A**			**D**		**B**
Discuss advantages and disadvantages of computer estimating						**A,B**	**C,D**
History is not important and should be disregarded in developing curriculum	**B,C**	**A**	**D**				
Category 2 Database Creation	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Understanding derivation of unit costs for labor, materials, equipment, and subcontractors						**A**	**B,C,D**
Discussion of equipment costs (i.e. Fuel, oil, grease, tires / tracks, maintenance) along with small tools and supplies (i.e. Hammers, etc)					**A**		**B,C,D**
Derivation of productivity factors by empirical method				**A**		**C**	**B,D**
Applying skills to derive total unit cost			**A**			**C**	**B,D**
WBS (Work Breakdown Structure) Code to breakdown and organize database	**B**			**C**	**A**	**D**	
Applying different wage rates (i.e. Union, open shop, prevailing wage rates)					**B**	**A,C**	**D**

Use of database to help with takeoffs					**A,B,C**	**D**	
Understanding inherent errors that may occur using unit price estimating (Oversimplification of quantities, not applying differing productivities based on specific jobsite requirements)					**A**	**B**	**C,D**
Ability to create a new database as well as copy an existing database for use				**A**	**C**		**B,D**
Set-Up and apply productivity rates for each item					**A**	**C**	**B,D**
Ability to create formulas to convert takeoff dimensions to formulate bid quantities					**A**		**B,C,D**
Understand current market pieces and conditions when creating and using databases					**B**	**C**	**A,D**
Category 3 Takeoffs	***1***	***2***	***3***	***4***	***5***	***6***	***7***
Ability to understand units associated with items during a takeoff (i.e.. Earthwork (cy), fine grade (sy), Lumber (mbf), etc						**A,C**	**B,D**
Understanding basic geometry				**A**		**C**	**B,D**
Completing of simple take-offs of isolated portions of work				**A**	**C**		**B,D**
Preparing a takeoff in which other can easily understand					**C**		**A,B,D**
Comparing take-offs with others to ensure quality and quantity are accurate				**C**	**A**	**B**	
Students should be able to takeoff single items using a database					**A**	**D**	**B,C**
Students should be able to takeoff assemblies using a database					**A**	**B,C,D**	

Student should be able to modify assemblies while completing take-off without changing database				A	B,C,D		
Student should be able to takeoff items not present in a database					A,C		B,D
Ability of students to takeoff items manually and apply them into an estimating program				A		C	B,D
Discuss advantages and disadvantages of elect iconic take offs						A,B,D	C
Discuss and apply certain shortcuts when completing take off (repetitive items)				C	A,D	B	
Explain / demonstrate different tools for take-offs (i.e. digitizer, on screen take off, etc)				C	D	A,B	
Category 4 Use of Assemblies	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Advantages and Disadvantages of assembly usage					A	B	C,D
Combine related WBS together to make common item take off faster				B	A,C	D	
Student should be able to identify all of the components needed to create an assembly				A,B			C,D
Student should be able to set up an assembly in the database				A,B		C	D
Student should be able to build logic (choices between materials) into the assembly			B	A		D	C
Student should be able to apply different formulas to each item of the assembly if necessary			A	B			C,D
Category 5 Report Creation	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Report with estimated overhead, profit, bond, and insurance				C	A	B	D

Create materials list from estimate				**A,C,D**	**B**		
Creating Unit Price estimates			**A**	**C**		**B,D**	
Ability of student to complete standard bid documents (bonds, non-collusive affidavit, etc)			**C**	**A**		**B,D**	
Student should be able to print detailed estimate with information relevant to client			**C**			**A,B**	**D**
Student should be able to print a report with a summary estimate sorted by cost code			**C**		**A**		**B,D**
Student should be able to print a materials report for a bid			**C**	**A**		**B,D**	
Student should be able to print a detailed estimate with add-ons allocated		**C**			**A**	**B,D**	
Convey to you client what you want them to know						**B**	**A,C,D**
Miscellaneous Items	***1***	***2***	***3***	***4***	***5***	***6***	***7***
Student should work with a team on a project using real plans and specs to produce an estiamte					**D**		**A,B,C**
Incorporating sub-quotes for a project with all subs						**A,B,C**	**D**
Student should be able to incorporate add-ons into a bid					**A**	**B,C,D**	
Student should be able to check a bid for errors						**B**	**A,C,D**
Student should be able to se-up a new estiamte from scratch				**A**		**B,C**	**D**
Discuss importance of field experience when creating an estimate					**C**	**A,B**	**D**
Discuess how each contractor does estimating different					**C**	**A**	**B,D**